Optical Photometric and Polarimetric Behaviors of Blazar Outbursts

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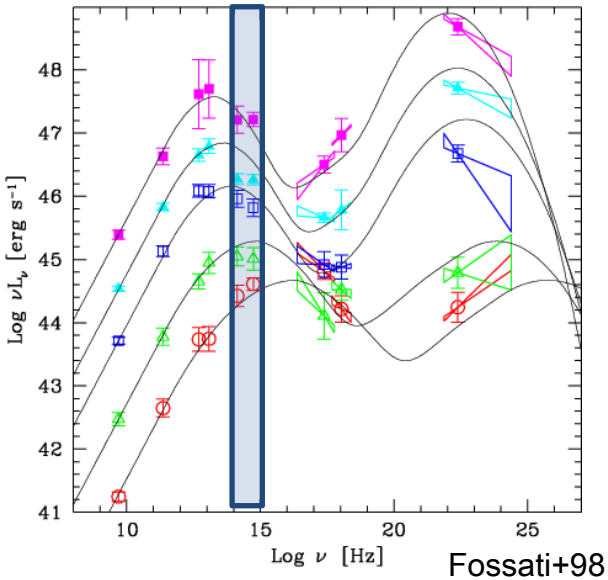
and Kanata team

Observational Property of Blazars

- Broad band radiation
  - Low energy component
    - ➢ Synchrotron radiation
  - High energy component
    - ➢ Inverse-Compton scattering radiation



Fossati+98

- Rapid and violent variability

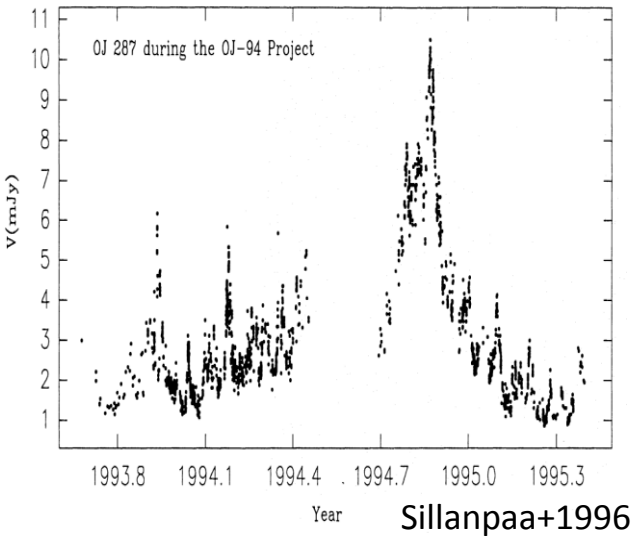
  Blazar variability has a various timescale from less than an hour to longer than years

- High polarization of synchrotron radiation
  - – Polarization shows a variation, and the behavior is complex.
    - ➢ The relation between the flux and polarization is unclear.

Polarization during an Outburst

- Blazars often show the large-amplitude brightenings, called as outbursts.
- A behavior of synchrotron polarization in the outburst is difficult to observe, because the outburst occurs unpredictably.

Example of the outburst



Sillanpaa+1996

- A polarization and its variation gives us clues of the physical parameters in the emitting region.

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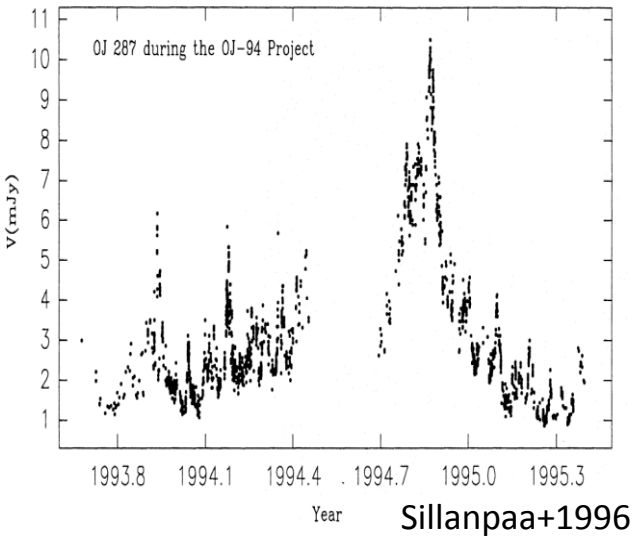


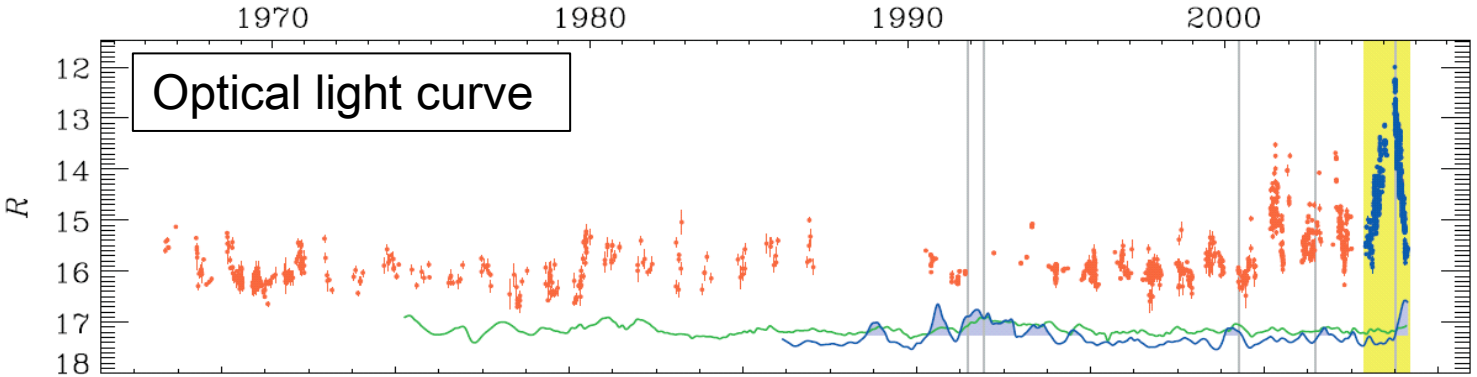
Sillanpaa+1996

- A polarization and its variation gives us clues of the physical parameters in the emitting region.

We investigate the origin of the outburst by obtained the variations of flux, spectral shape and polarization.

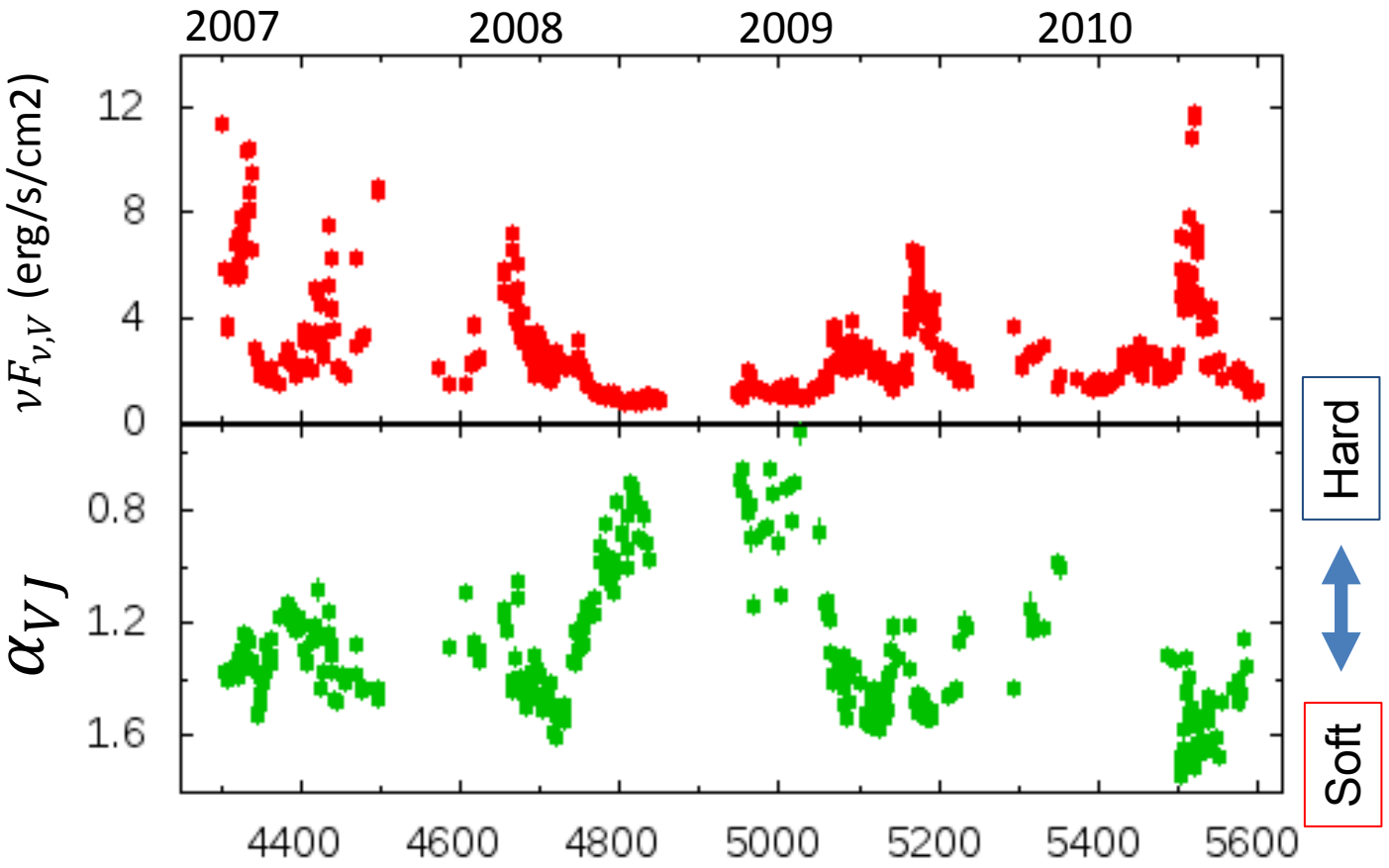
Focus Object : 3C 454.3

- One of the most famous blazars (z = 0.859).
- In 2005, the object was in an exceptional outburst.
- Similar outbursts had been reported every year since 2007.
- We have monitored since 2007 in multi-band photopolarimetric mode in the optical and near-infrared (NIR) bands.



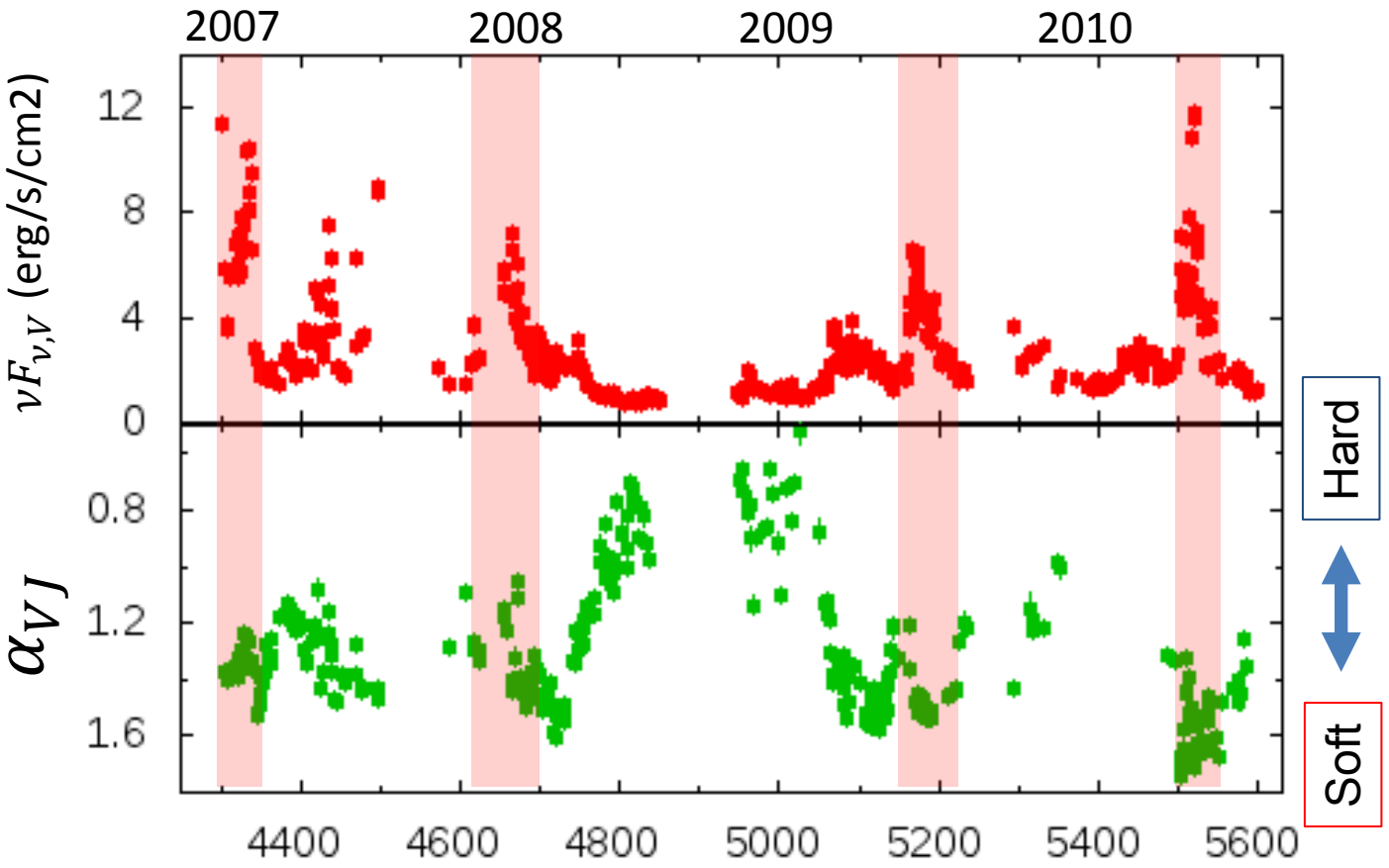
Villata+ 2006

Several Outbursts from 2007 to 2010



There were four outbursts during our monitoring.
The shapes of these outbursts were different.
The 2010 outburst was the softest.

Several Outbursts from 2007 to 2010



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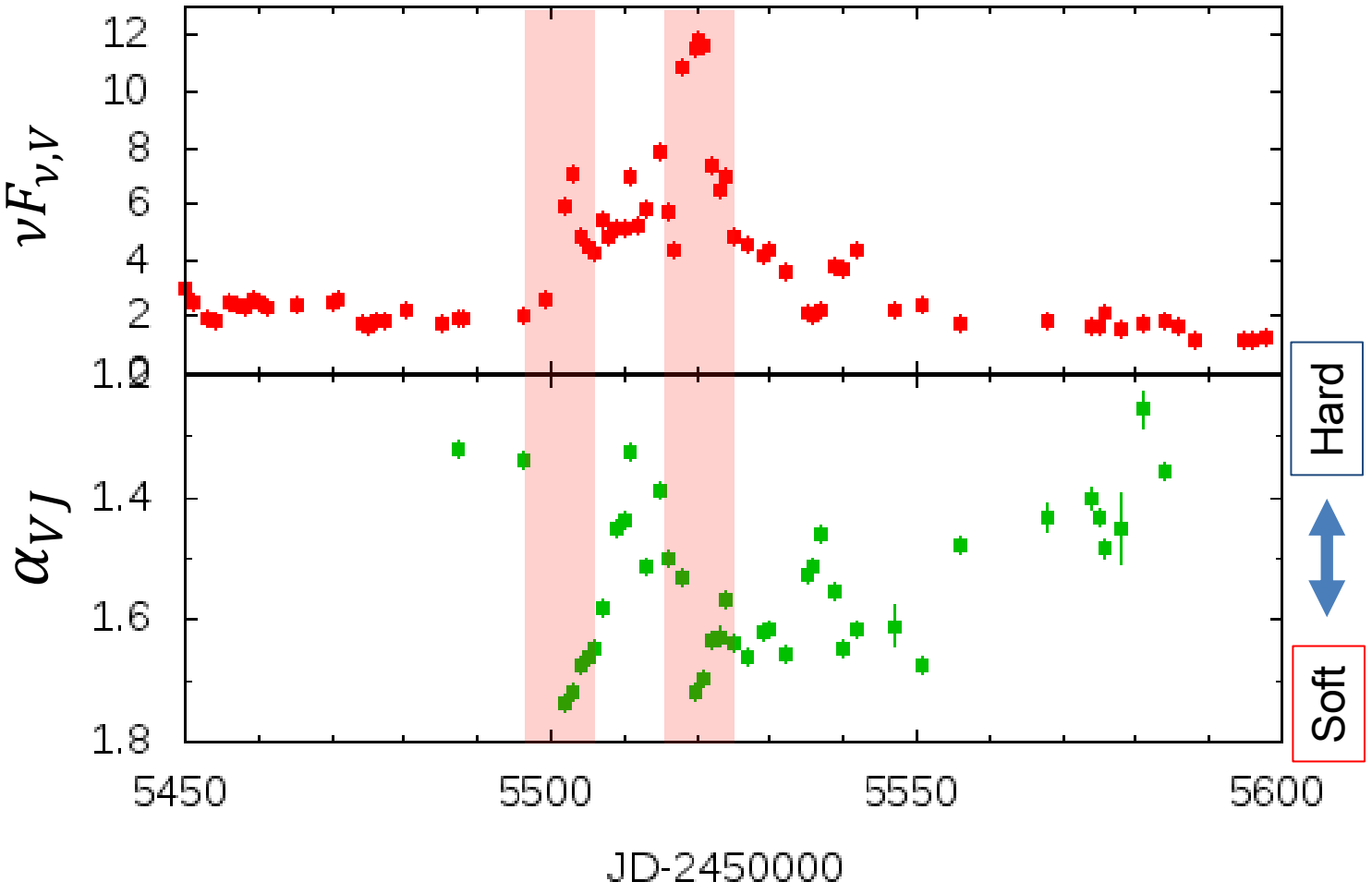
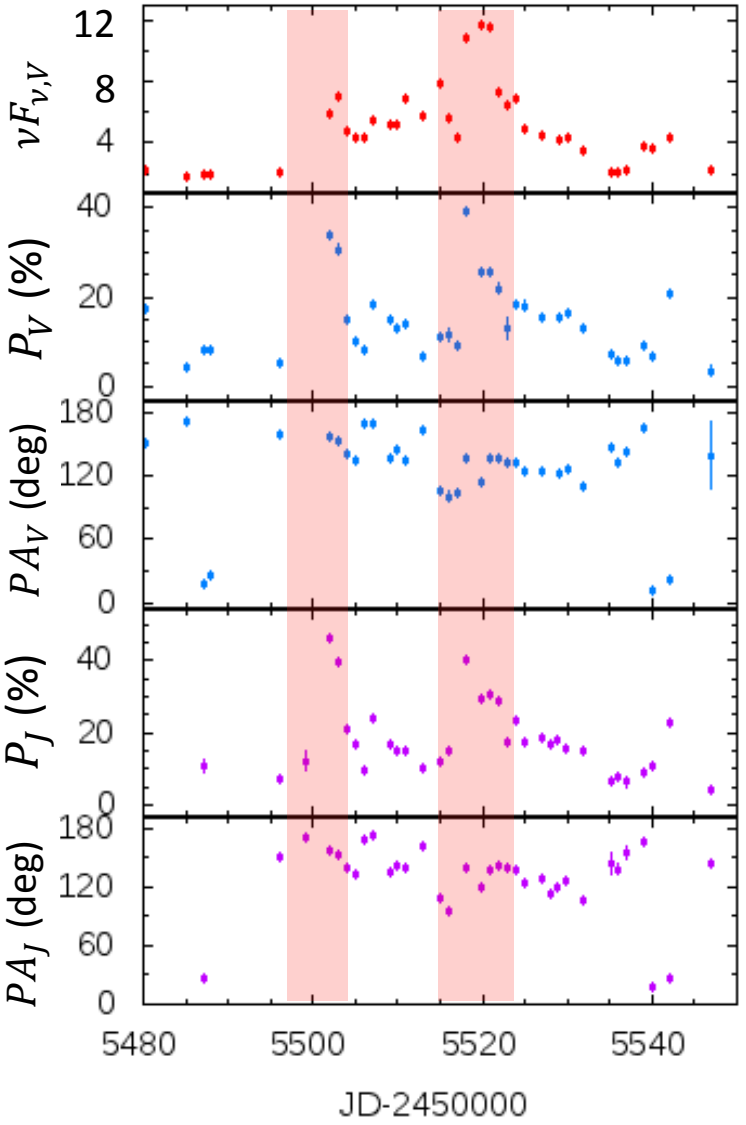
2010 outburst



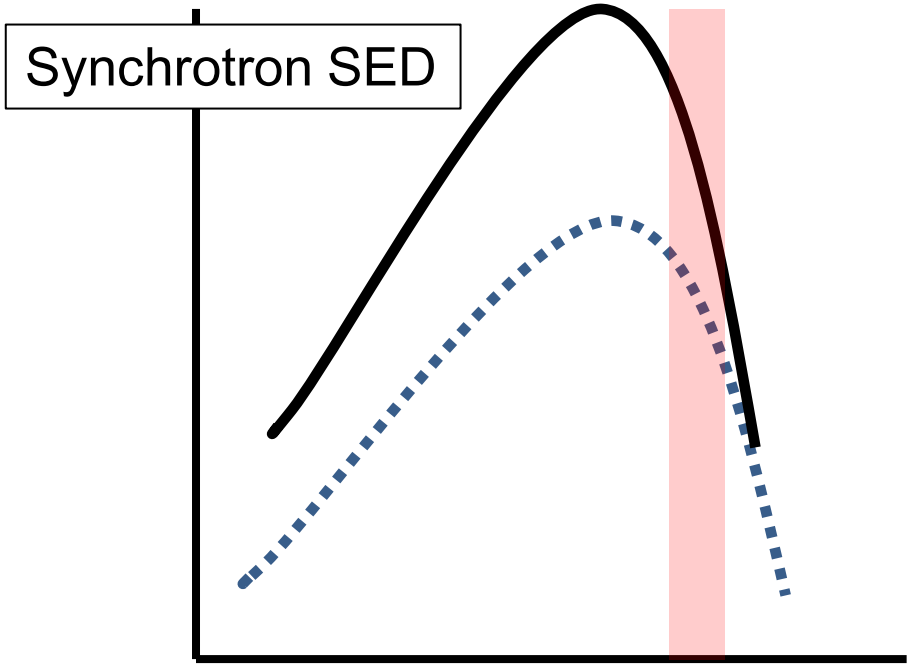
During the rapid brightenings, the object became softer.

2010 Outburst : FDP

- The polarization became high in the rapid brightenings.
- The maximum P in the NIR band, (P_J=46%), was higher than that in the optical band, (P_V =38%).
- The frequency-dependent polarization (FDP) are shown in the first brightenings.
- Angle of polarization is distributed around 160 degree.
- There is no rotation event of the polarization vector.



How Many Components During Outburst



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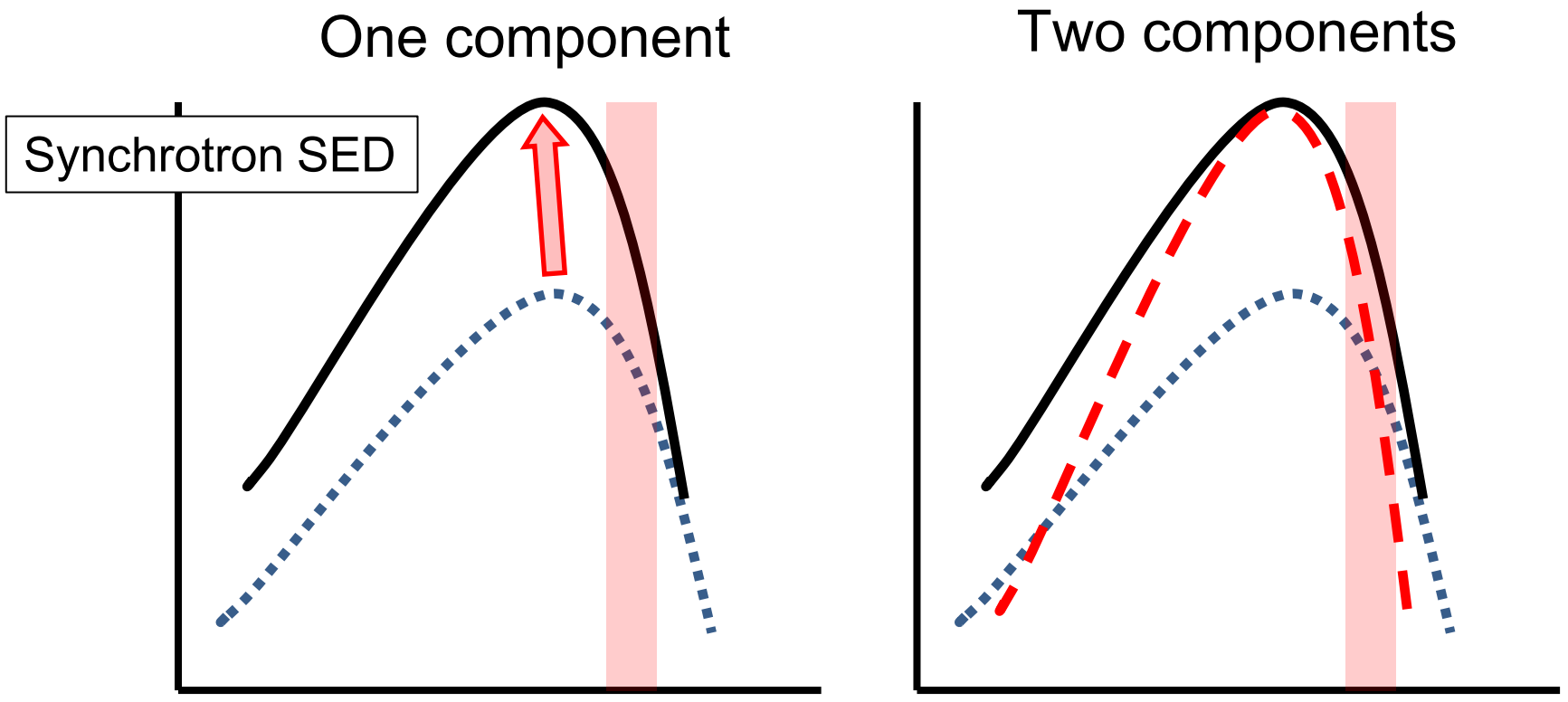
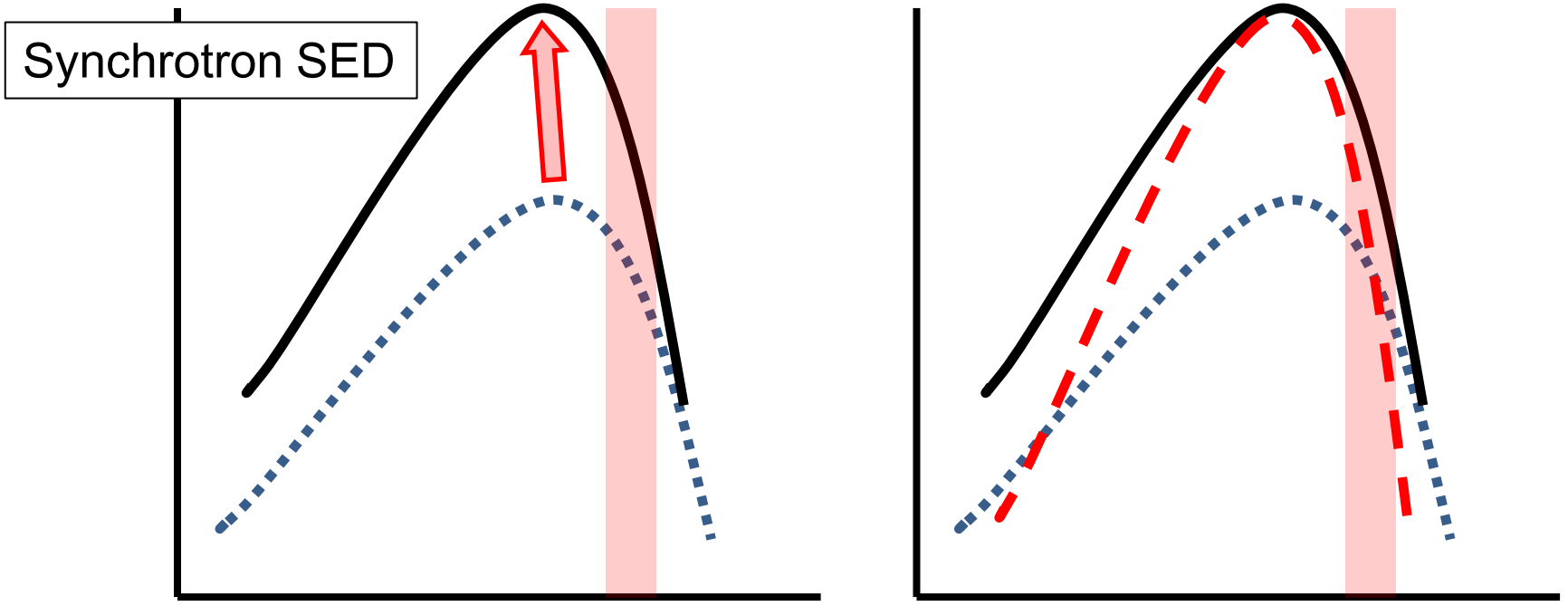


How Many Components During Outburst

One component

Two components



- FDP

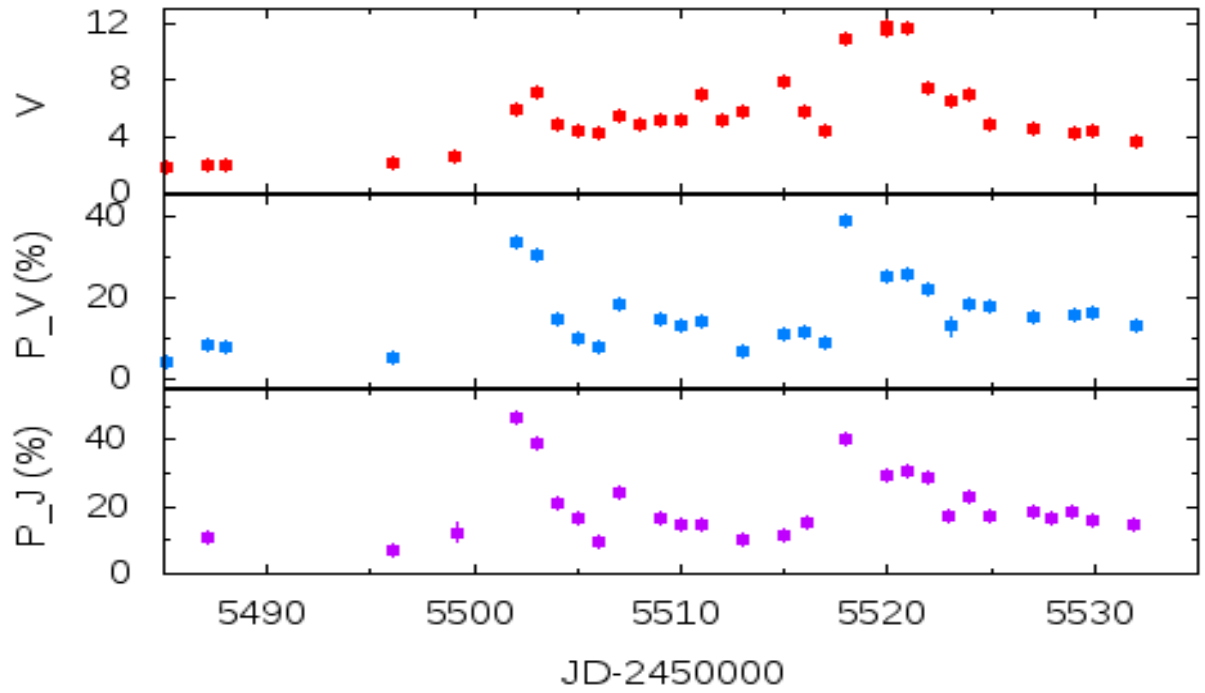
One zone : Same

Multi zones : Different

FDP indicates that there are two components during the brightening.

Estimate Brightening Component

We estimate the fluxes and polarization vectors of brightening components by subtracting the base component from the observed data.



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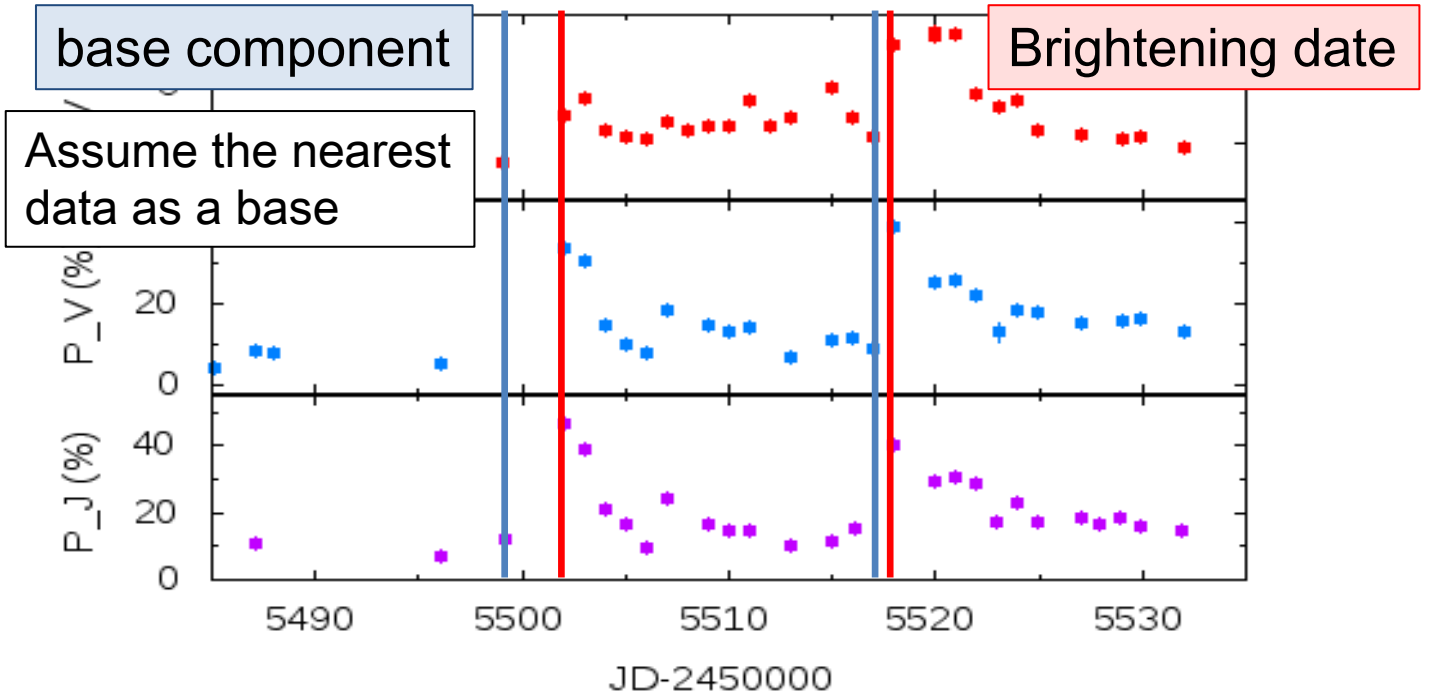

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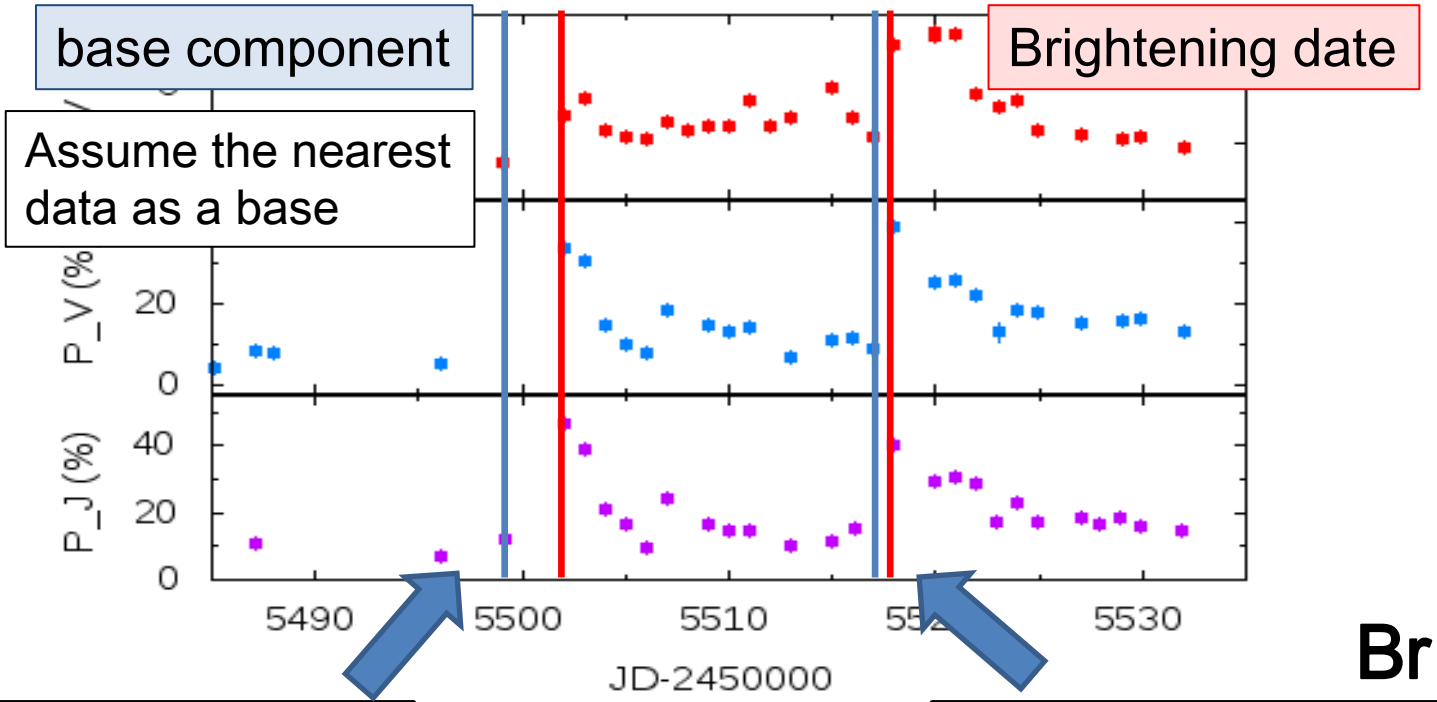


Br 1

$$\Delta F_J = 6.78 \times 10^{-11}$$
$$\Delta P_J = 66\ \%$$
$$\Delta \alpha_{VJ} = 1.91$$

Similar P

Br 2

$$\Delta F_V = 6.57 \times 10^{-11}$$
$$\Delta P_V = 62\ \%$$
$$\Delta \alpha_{VJ} = 1.57$$

Polarization Emitted from Shocked Region

By the shock, the magnetic field of the emitting region should be compressed and aligned perpendicular to the shock moving direction.
A degree of polarization of the synchrotron radiation emitted from this shock region can be estimated as;

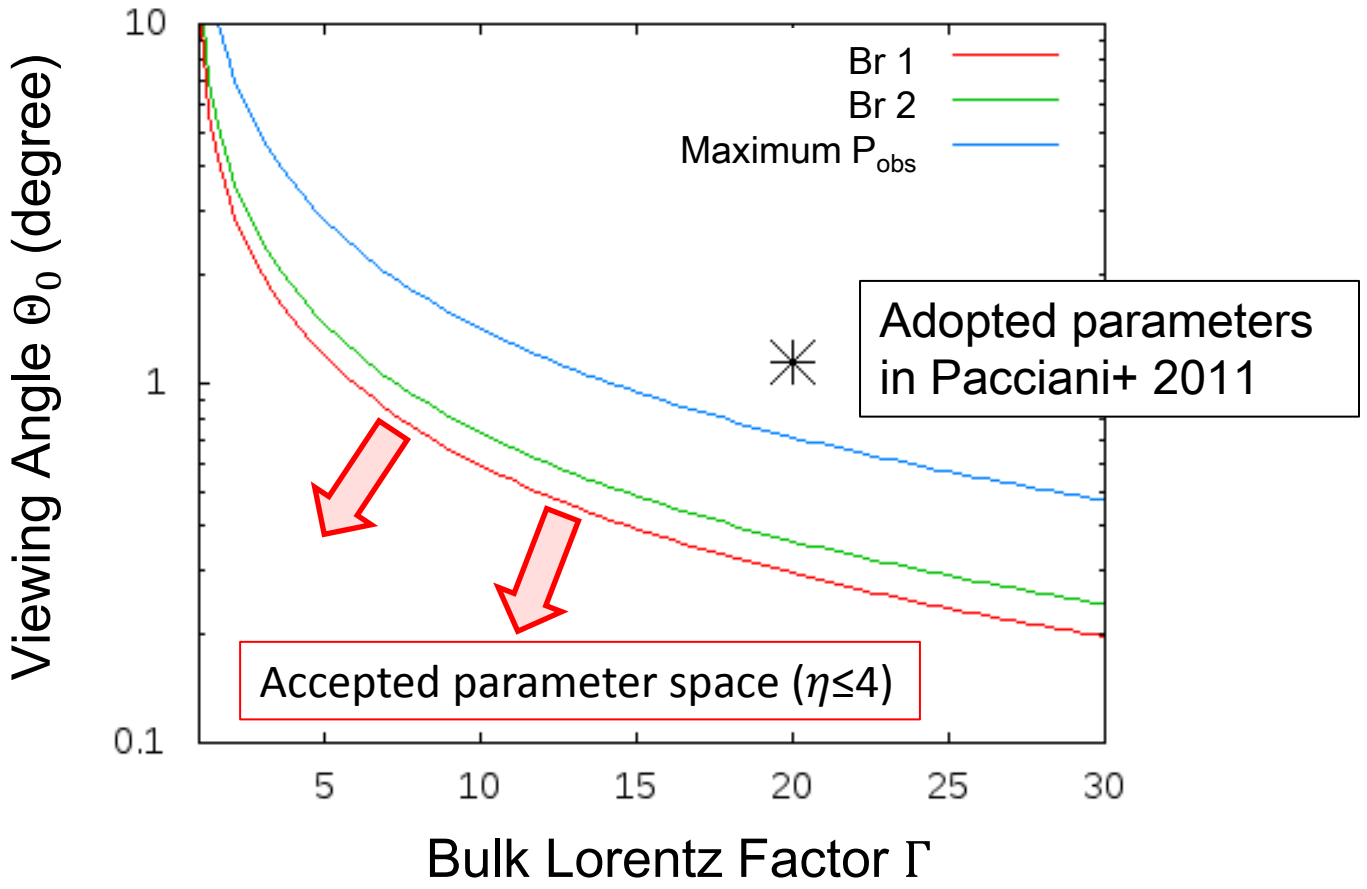
$$\mathrm{P} = \Pi_s \frac{|\eta^2 - 1| sin^2\theta_c}{(1 + cos^2\theta_c)\eta^2 + sin^2\theta_c} \qquad \Pi_s = \frac{\alpha+1}{\alpha+5/3}$$

Π_S is the theoretical maximum polarization.
Synchrotron is emitted at an angle θ_c to the plane of compression.
η is a compression parameter, $\eta = \rho_{down}/\rho_{up}$. η is limited from the Rankine-Hugoniot relation $\boldsymbol{(\eta \leq 4)}$.
The viewing angle in the observer frame, Θ_o, is represented as;

$$\tan\Theta_o = \frac{\cos\theta_c}{\Gamma\left(\sin\theta_c + \sqrt{1 - \Gamma^{-2}}\right)}$$

Hughes+ 1985

Bulk Lorentz Factor and Viewing Angle



The adopted parameter pair in Pacciani+ 2011 is not included in the accepted parameter space.

Accepted Situation

- The parameters in Pacciani+ (2011) are estimated from the whole SED from the radio to gamma-ray bands during the 2010 outburst.
  - The parameters are estimated from the sum of the spectra from all emission regions.
- Our estimated parameters are calculated from the P of the rapid brightening components.

➢ Γ and/or Θ_o of rapid brightenings are different from those of whole emission region.

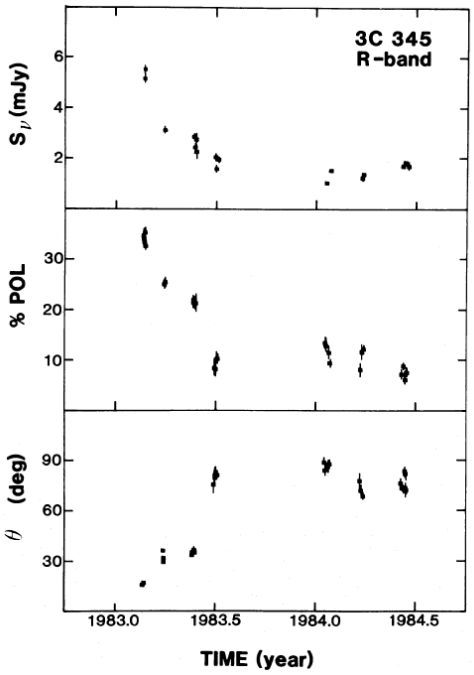
Summary

- 3C 454.3 showed four large-amplitude outbursts from 2007 to 2010.
- Flux, spectral shape and polarization vector varied during the 2010 outburst.
- The object became softer during the rapid brightenings.
- Observed degrees of polarization in the rapid brightenings became high, and showed the frequency-dependent polarization.
- Γ and/or Θ_o are different between the rapid brightenings and the whole emission regions.

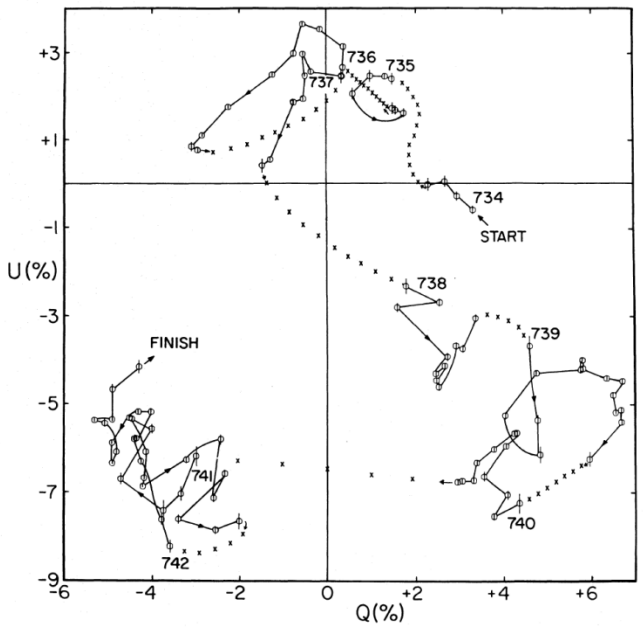
Thank you for your attention!

Flux and Polarization

Smith+ 1986



Moore+ 1982



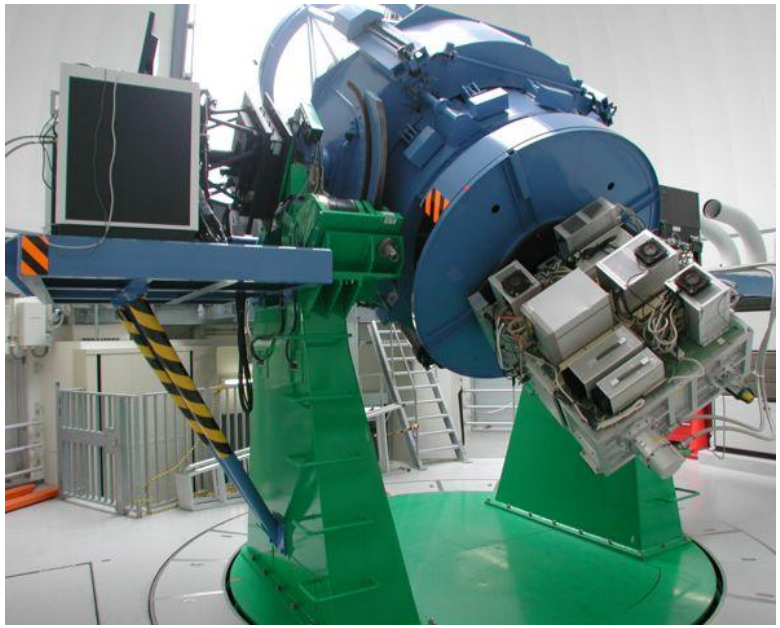
- Positive correlation between the flux and polarization degree (e.g. Smith+ 1986)
- Apparently random motion in the QU plane (e.g. Moore+ 1982)
- Several recent papers suggest that the polarization vector can be separated in two components; short- and long-term components.

Using Instrument

- Kanata telescope

(@Higashi-Hiroshima Obs. Japan)

  - 1.5-m telescope
  - Dense and continuous observations
- TRISPEC
  - Simultaneous optical and near-infrared photometry
  - Linear polarization

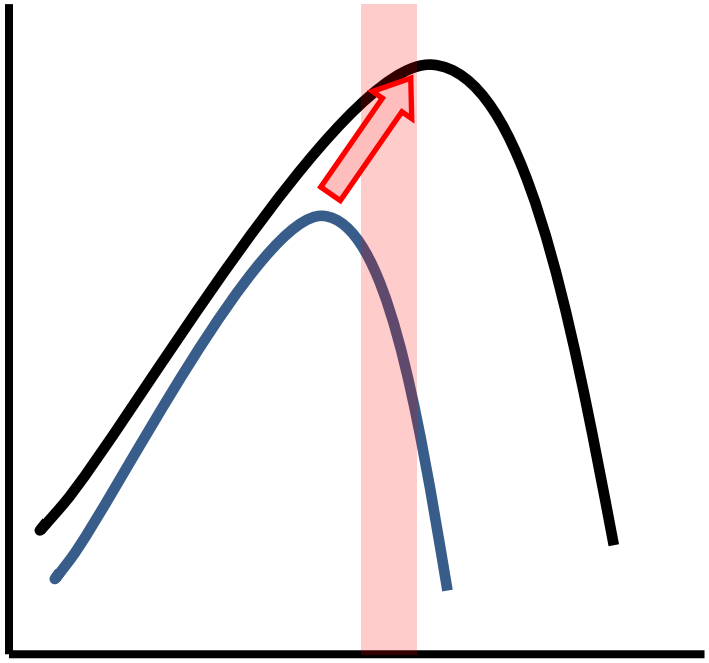


Kanata and TRISPEC are suitable for monitoring blazars

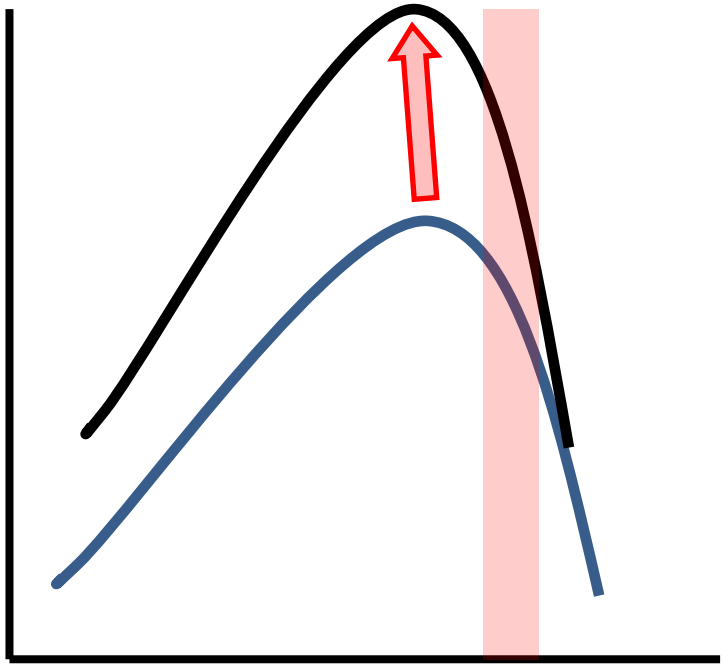
Synchrotron peak shift

- In general, blazars become harder, when the objects are bright.
- Accept two possibilities of the origin of variability
  1. Variation of Doppler beaming
  2. Variation of intrinsic distribution of emitting particles
- In the 2010 outburst, the color has become softer.

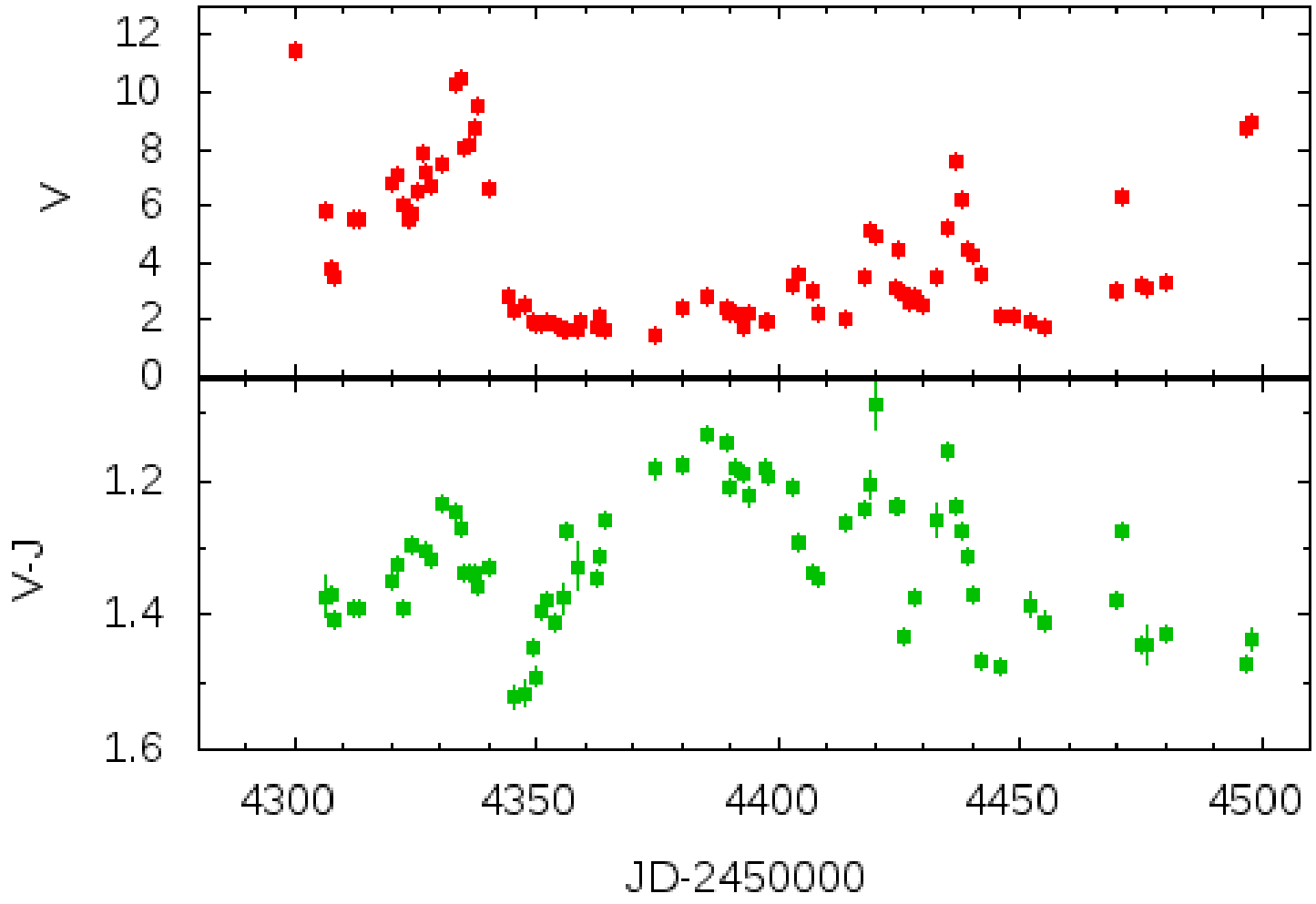
General case



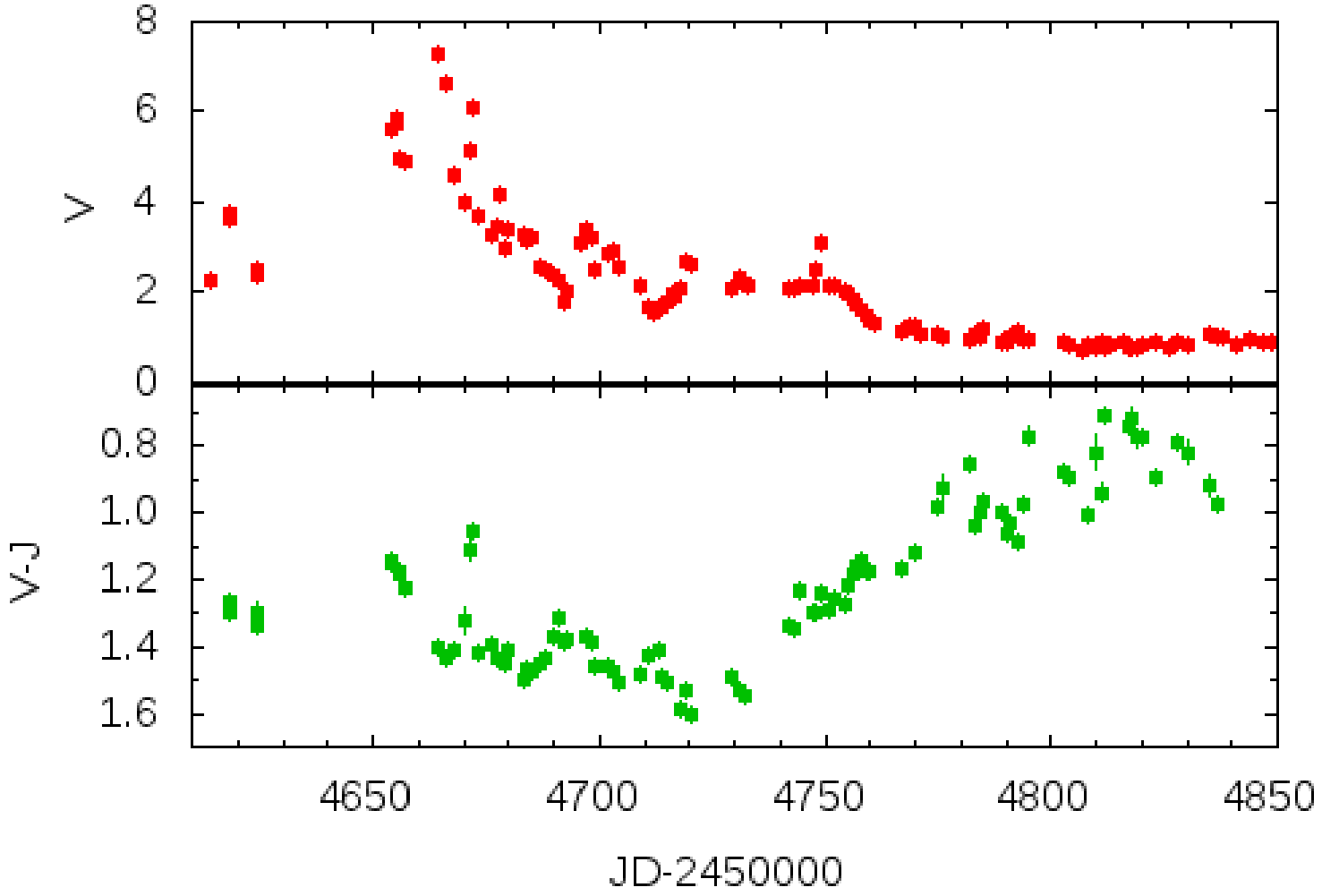
Case in 2010 outburst



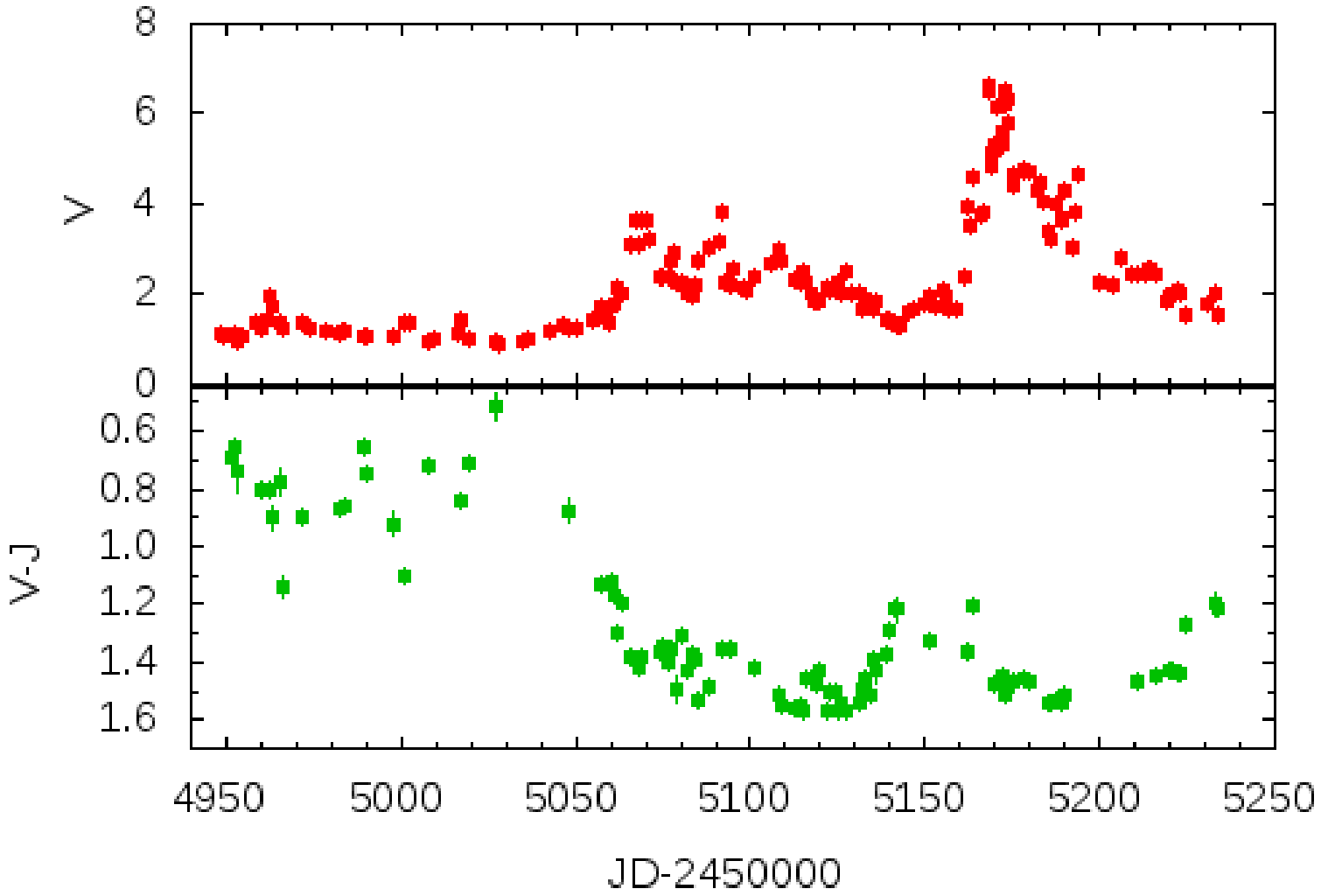
2007



2008



2009


V
V-J
JD-2450000
8
6
4
2
0
0.6
0.8
1.0
1.2
1.4
1.6
4950
5000
5050
5100
5150
5200
5250

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➢ Emission regions are different.

- Γ and/or Θ_o are different between the rapid brightening and the whole emission regions.
  - $\Gamma_{br} = \Gamma_{wh} \Rightarrow \Theta_{o,br} < \Theta_{o,wh}$
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